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OPTIMUM TEMPERATURES FOR FLOWER SEED GERMINATION[1]

GEO. T. HARRINGTON

(WITH TEN FIGURES)

The proper conditions for the germination of flower seeds is a subject upon which but little work has been published. During the spring of 1912, preliminary work was done in the seed laboratory of the United States Department of Agriculture on the temperature conditions best suited for the germination of a few of the more common flower seeds. During the winter and spring of 1913–1914, further work was done with the same species investigated in 1912, and with a few additional species. The publication of the results has been unavoidably delayed for several years. In the meantime, the recommendations included herein have been followed by the seed laboratory with good results.

The seeds included in the investigation were those of *Impatiens balsamina*, *Eschscholtzia californica*, *Iberis amara*, *Cosmos bipinnatus*, *Kochia scoparia*, *Delphinium ajacis*, *Calendula officinalis*, *Reseda odorata*, *Tropaeolum majus* and *T. minus*, *Viola tricolor*, *Petunia hybrida*, *Dianthus chinensis*, *Papaver* spp., *Portulaca splendens*, *Antirrhinum majus*, *Lathyrus odoratus*, and *Zinnia elegans*. Only a small number of samples of some kinds was included in the actual investigation. The subsequent experience of the seed laboratory, however, includes the germination of such kinds of seeds both at

[1] Report of work done while in the Seed Laboratory, United States Department of Agriculture.

the temperatures recommended and at other temperatures, and has verified these conclusions. Duplicates of one hundred seeds each were used in making nearly every germination test. In a few tests duplicates of only fifty or seventy-five seeds each were available, on account of the small size of the samples used.

Method and apparatus

The sweet pea and nasturtium seeds were tested in moist canton flannel, using two thicknesses of the flannel under the seeds and two thicknesses over them. Balsam, California poppy, cosmos, larkspur, marigold, mignonette, pansy, and zinnia seeds were tested between moist blotting papers, two thicknesses above and two below. Candytuft, cypress, petunia, pink, poppy, portulaca, and snapdragon seeds were tested on top of four thicknesses of moist blotting paper. In the tests which were made in 1914 the poppy seeds were tested both between moist blotting papers and on top of moist blotting paper.

All tests were made in standard water-jacketed copper germinating chambers, and were continued until no more seeds or only an occasional one germinated. The progress of germination was carefully watched, and all germinated seeds were counted and thrown away at frequent intervals in the tests which were made in 1912, and each day after germination began in the tests which were made in 1914.

The seeds were tested with the use of the constant temperatures 15°, 17.5°, 20°, 22.5°, 25°, 28°, and 30° C, and with daily alternations of temperature between 20° C. as the lower temperature and 28°, 30°, 31°, 32°, 35°, and 37° as the higher temperatures in the different alternations. The temperatures named as the higher temperatures in the alternations are those indicated by thermometers inserted in the tops of the chambers, and are 1° or 2° C. higher than the highest temperatures reached within the blotters or cloths in which the seeds were being tested. The alternations include some in which the seeds were kept from four to seven hours daily in a chamber which was constantly maintained at the higher temperatures, and the rest of the day in another chamber at the lower temperature; and others in which only one chamber was used,

this chamber being slowly heated during the forenoon, and cooled either slowly or rapidly as desired during the afternoon. When only one chamber was used the heating was accomplished by means of a properly adjusted gas flame below the chamber, and the cooling by means of a graduated stream of cold water in the top of the water jacket.

The species investigated may be divided into two groups: (1) those whose seeds germinate well at any constant temperature from 17.5° to 22.5° C., and also with temperature alternations; (2) those whose seeds require a temperature cooler than 20° C. for complete germination. Some of the samples in each group contained many dead seeds, or seeds incapable of germination at any temperature.

Results

Although a direct comparison between the tests made during the two periods (1912 and 1914) is impossible, the results of all the tests can best be discussed together. They will be considered from three standpoints: (1) the effect of alternating versus constant temperatures; (2) the effect of the different temperatures upon the germinating capacity; and (3) the effect of the different temperatures upon the rapidity of germination.

Alternating versus constant temperatures

All the species included in the investigation, with the possible exception of petunia, germinated as completely and as quickly with a favorable constant temperature as with any alternation of temperatures. It should be remembered, however, that taking the seeds out of the chambers to count those germinated introduced a brief change of temperature which may not have been entirely without effect. The influence of this brief temperature change, if it has any, would be greater when the germinated seeds are counted every day or two as in these experiments, than if they were counted less frequently.[2]

[2] While the use of an alternation of temperatures does not seem to be necessary for satisfactory germination of the kinds of seeds treated in this paper, it is very desirable, and in some cases imperatively demanded, with many other kinds of seeds. This subject will be treated in an article to appear shortly in the *Journal of Agricultural Research*.

It may be convenient in seed testing laboratories to use alternating temperatures in conducting germination tests of some of the kinds of seeds considered, in order to conform to methods established for use in testing the germination of other kinds of seeds. This matter will be discussed later.

GERMINATING CAPACITY

Twelve of the species studied belong in group 1. Table I shows the results, so far as total germination is concerned, of the

TABLE I

GERMINATION OF FLOWER SEEDS OF GROUP 1

SEEDS	AVERAGE PERCENTAGES OF GERMINATION										
	First series of tests*						Second series of tests*				
	No. of lots	20° C. 20°–28° 20°–30° 20°–31° 20°–32°	20°–35°	20°–37°	28°	30°	No. of lots	15°	17.5° 20° 22.5° 20°–30°	25°	* 30°
Balsam	1	98 to 99	98	98	98	....	3	94	94 to 98	97	98
Cal. poppy	2	62 to 70	62	62	59	....	1	72	77 to 85	74	68
Candytuft	2	74 to 80	83	70	74	62	5	79	78 to 80	78	76
Cosmos	1	80 to 85	....	80	....	....	1	....	87 to 92	....	90
Cypress	1	91 to 98	88	88	84	....	2	76	78 to 80	74	78
Marigold	....	.....	....	....	....	....	4	66	62 to 64	62	38
Mignonette	2	68 to 71	72	66	62	....	3	73	66 to 71	65	61
Petunia	2	67 to 74	64	56	70	....	2	76	71 to 76	79	80
Pink	1	90 to 96	90	92	90	....	7	89	88 to 91	87	87
Portulaca	1	86 to 94	83	90	86	87	1	71	74 to 80	75	71
Sweet pea	....	.....	....	....	....	....	2	84	84 to 94	84	84
Zinnia	1	90 to 94	96	91	91	....	2	79	79 to 85	78	74

* The two series of tests were entirely distinct, no lot of seeds was used in both series.

experiments with this group. Each of the twelve species germinated about equally well at any constant temperatures from 17.5° to 22.5° C., and with the temperature alternations 20°–28°, 20°–30°, 20°–31°, and 20°–32° C.

Seeds of balsam, candytuft, cypress, marigold, mignonette, petunia, pink, sweet pea, and zinnia germinated as completely at 15° C. as at warmer temperatures. Seeds of balsam, candytuft, cosmos, cypress, petunia, pink, portulaca, sweet pea, and zinnia germinated as completely at some or all of the constant tempera-

tures warmer than 22.5° C. as at cooler temperatures. Four of these, candytuft, pink, portulaca, and zinnia, germinated somewhat less completely at 30° than at 25° or 28° C. Seeds of balsam, California poppy, candytuft, cosmos, cypress, mignonette, pink, portulaca, sweet pea, and zinnia germinated as completely with one or both of the warm temperature alternations, 20°–35° and 20°–37° C., as with cooler temperatures.

TABLE II

GERMINATION OF SEEDS AT DIFFERENT TEMPERATURES

Temperature	Average percentages of germination								
	Larkspur		Nasturtium	Pansy		Poppy		Snapdragon	
	1912 (1 lot)	1914 (3 lots)	1914 (2 lots)	1912 (1 lot)	1914 (1 lot)	1912 (3 lots)	1914 (8 lots)	1912 (1 lot)	1914 (3 lots)
Icebox	53	86	.....	.....	.....	.....	72	.....	38
15° C.	.....	81	78	.....	81	.....	78	.....	66
17.5°	67	63	78	.....	87	77	75	.....	67
20°	48	28	74	46	78	70	60	48	62
22.5°	.....	1	66	.....	78	.....	49	.....	59
20°–28°	38	.....	.....	48	.....	70	.....	44	.....
20°–35° (cooled rapidly)	34	.....	.....	48	.....	70	.....	52	.....
20°–31°	29	.....	.....	.....	.....	.....	.....	.....	.....
20°–30°	25	8	65	56	74	66	52	46	52
20°–32°	11	.....	.....	45	.....	58	.....	48	.....
20°–30° (cooled slowly)	.....	.....	.....	48	.....	51	.....	48	.....
20°–37°	7	.....	.....	36	.....	44	.....	48	.....
25°	.....	.....	60	.....	62	.....	.....	.....	.....
28°	.....	.....	.....	39	.....	26	.....	36	.....
30°	.....	.....	7	.....	28	.....	6	.....	19

Seeds of larkspur, nasturtium (2 species, 1 sample each), pansy, poppy (a number of species), and snapdragon belong to group 2, which germinated most completely at a temperature cooler than 20° C. In 1914 the larkspur, poppy, and snapdragon seeds were tested in an icebox in which the average temperature was about 8° C., as well as with the temperature conditions used with the other kinds of seed.

Table II shows the average percentages of germination of seeds of group 2 under the different temperature conditions, arranged in the order of increasing average temperature of the germination

blotters, regardless of the highest temperature reached in the different alternations.

Pansy seeds germinated more completely at 17.5° than at 15° C.; larkspur and poppy more completely at 15° than at 17.5°; while with nasturtium and snapdragon seeds there was no difference between these two temperatures. Although the larkspur seeds tested in 1914 germinated even more completely in the icebox than at 15° C., the slowness of germination in the icebox makes the use of so low a temperature undesirable. Furthermore, the difference in total germination in favor of the icebox temperature was only with one lot of seeds, the other two germinating practically the same as at 15° C.

The rather poor samples of pansy and snapdragon seeds which were tested in 1912 germinated more completely with an alternation of temperatures than with a constant temperature of 20° C. These samples were not tested with the cooler constant temperatures which proved most favorable in 1914. The decrease in the average percentage of germination with rise in temperature above the optimum was rapid in the case of larkspur, somewhat slower in the poppy, and slow and gradual in nasturtium, pansy, and snapdragon. The low optimum temperature for germination of larkspur and poppy is reflected in the recognized practice of sowing these seeds in the fall or very early in the spring, when the ground is cold. It is significant, too, as showing the adaptation of the seed to the general physiology and life history of the plant, that poppies fail to make satisfactory growth if started after the advent of warm weather when the soil temperature is above the optimum for germination of poppy seeds. In the case of larkspur and poppy, there was a great deal of variation in the relation of temperature to completeness of germination between even the different lots of the same kind of seeds. These two species will be considered separately in the following pages.

TEMPERATURE REQUIREMENTS FOR GERMINATION OF LARKSPUR SEED.—Fig. 1 shows graphically the contrast in response to different temperatures of two different lots of larkspur seeds, tested simultaneously in 1914. Each of the three lots tested in 1914 germinated much more completely in the icebox than at 17.5° C. Fig. 2 shows the total percentages of germination of one lot of

larkspur seeds with the different temperature conditions used in 1912. The different alternations are arranged from left to right

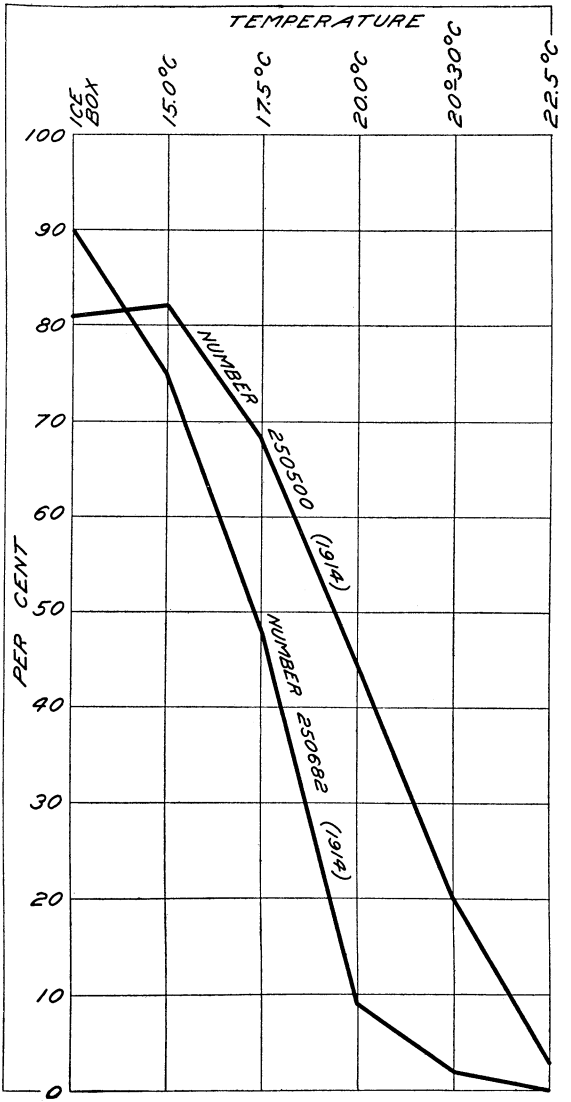

FIG. 1.—Germination of two lots of larkspur seeds

in the order of increasing mean temperature in the blotters. The percentage of germination decreased regularly as the temperature

at which the germination test was made increased from 17.5° to 28° C. The percentage of germination was 14 per cent less in the icebox than at 17.5° C., but greater than at any temperature warmer than 17.5° C. No record was kept of the temperature

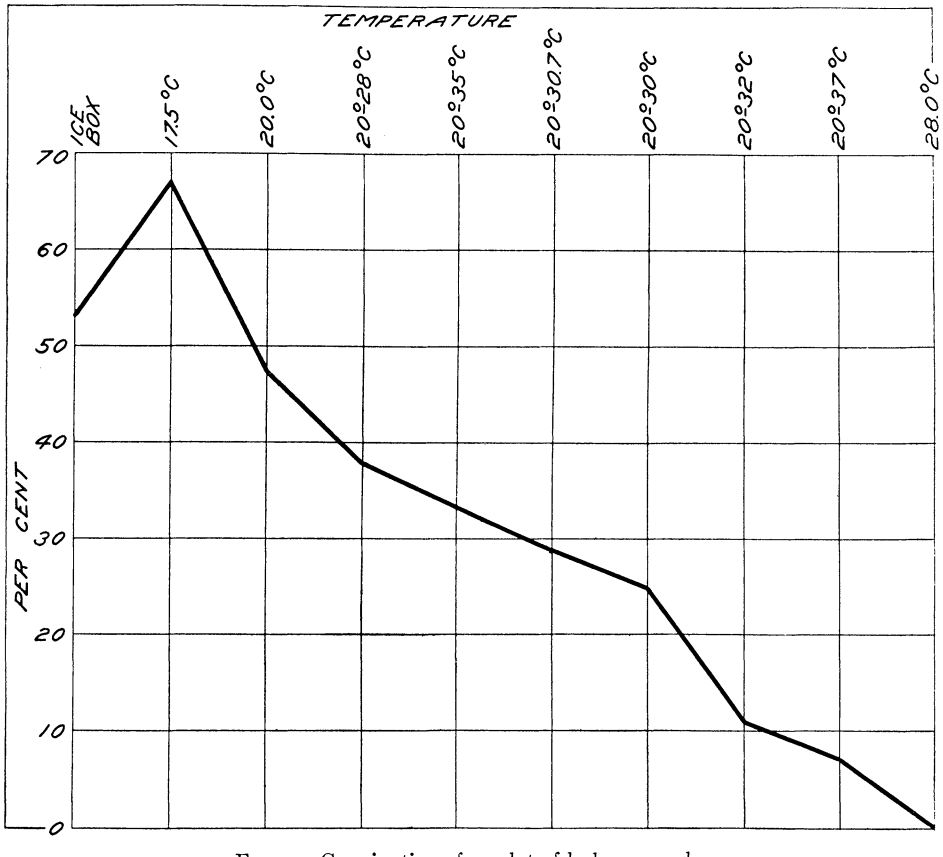

FIG. 2.—Germination of one lot of larkspur seeds

in the icebox, but it was probably cooler than in 1914, when each of the three samples tested showed a higher percentage of germination in the icebox than at 17.5° C.

TEMPERATURE REQUIREMENTS FOR GERMINATION OF POPPY SEED.—One lot of poppy seeds used in the investigations in 1912 was of the opium poppy, *Papaver somniferum*, the other two lots

were not determined as to species. In 1914 three lots of seeds of *Papaver somniferum*, three lots of the horticultural variety "Shirley" of *Papaver rhoeas*, and two lots of an undetermined species were used. Table III gives the percentages of germination of the eight lots which were tested in 1914. In general, the seeds of *Papaver somniferum* were much less sensitive to temperature conditions than were the seeds of the other species. Fig. 3, constructed from the averages in table III, illustrates the relation of temperature to completeness of germination of the three species of *Papaver* included in the tests of 1914. Fig. 4 shows the differ-

TABLE III

GERMINATION OF DIFFERENT SPECIES OF POPPY AT DIFFERENT TEMPERATURES

TEMPERATURE	PERCENTAGES OF GERMINATION										
	Papaver somniferum				Papaver rhoeas var. "Shirley"				Papaver sp.		
	No. 5440	No. 250482	No. 250768	Averages	No. 250224	No. 250693	No. 250752	Averages	No. 250196	No. 250197	Averages
Icebox	55	78	87	73	58	76	76	70	56	88	72
15° C	70	79	94	81	58	88	81	76	62	90	76
17.5°	65	78	88	77	58	78	81	72	61	90	76
20°	66	78	78	74	44	38	36	39	48	90	69
20°–30°	52	76	64	64	38	22	21	27	54	88	71
22.5°	58	78	64	67	28	39	16	28	24	84	54
30°	10	26	6	14	1	0	2	1	0	1	1

ences in germination of three lots of seed of *Papaver somniferum* with different temperatures. The temperature alternation 20°–30° C. represents a mean temperature in the blotters of practically 22.5° C. The equivalent value of these two temperature conditions for the germination of larkspur and poppy seeds is evident from the results.

GERMINATION OF POPPY SEED BETWEEN BLOTTERS AND ON TOP OF BLOTTERS.—As previously stated, poppy seeds were tested in 1914 both on top of and between double thicknesses of moist blotting paper. In the icebox the average percentage of germination on top of blotters was sixty-seven, between blotters seventy-three. At 15° C. the average percentages were respectively eighty and seventy-five. In the tests with each of the other temperature

conditions, the average percentages of germination on top of blotters and between blotters differed from each other by less

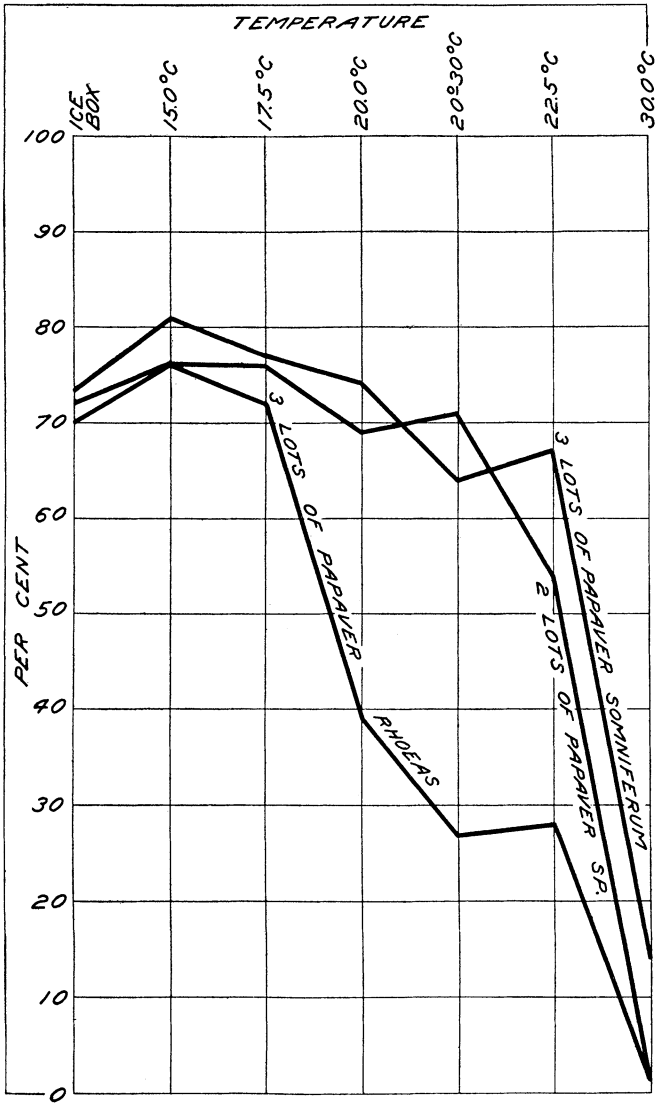

FIG. 3.—Germination of three species of *Papaver*

than 2 per cent. Averaging the results of the fifty-six tests (seven tests of each of eight lots of seeds) on top of blotters, and fifty-six

between blotters, gives fifty-five as the average percentage of germination in each case. There is, then, no advantage in either

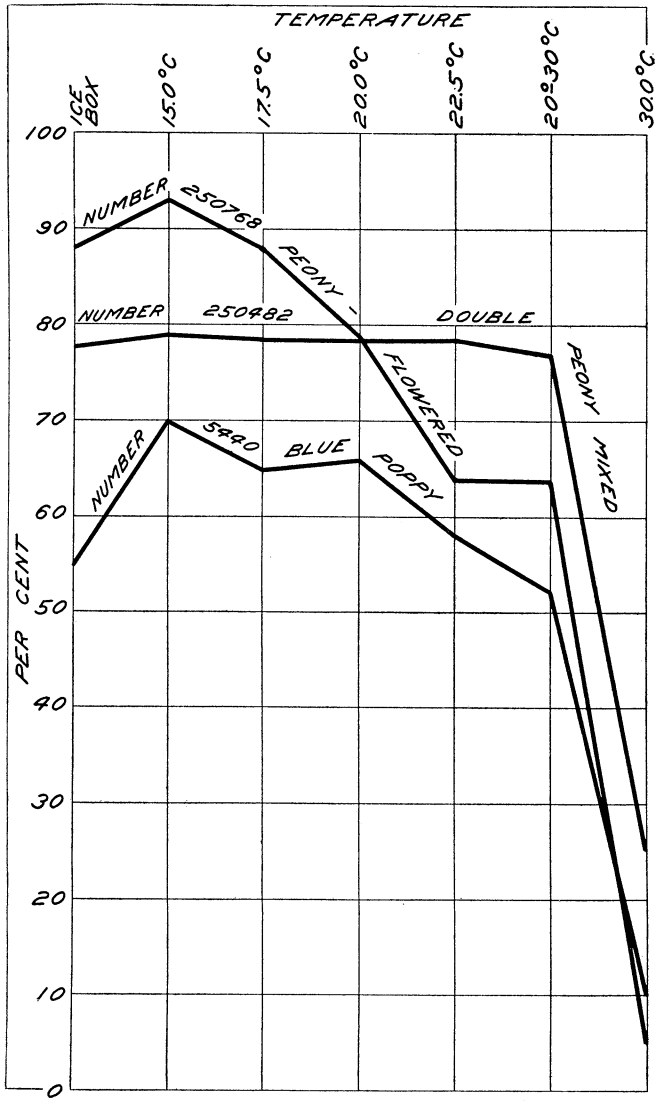

FIG. 4.—Germination of three lots of *Papaver somniferum*

method from the standpoint of completeness of germination. The position of the seeds, however, did affect the rapidity with

which germination took place in the icebox, as will be shown in the following section.

RAPIDITY OF GERMINATION

Under favorable temperature conditions, five days were required for germination tests of balsam and cypress seeds; six days for cosmos, marigold, pink, portulaca, and zinnia; eight days for California poppy, candytuft, mignonette, and opium poppy (*Papaver*

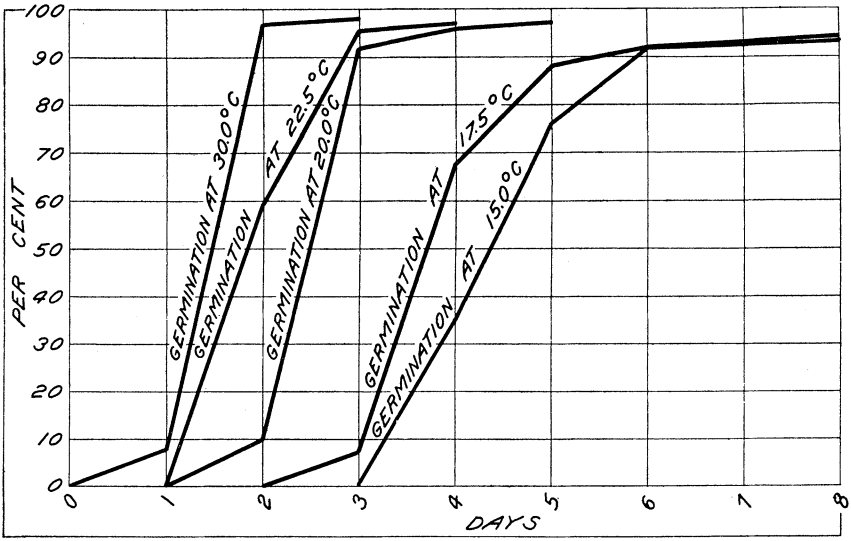

FIG. 5.—Average rate of germination of three lots of balsam seeds

somniferum); ten days for nasturtium, other species of poppy, petunia, snapdragon, and sweet pea; twelve days for pansy; and fifteen days for larkspur. For the germination of strong rapidly germinating lots of seeds, less than the number of days indicated is required. On the other hand, sometimes a very poor lot of seeds or a lot which, although producing vigorous seedlings, germinates slowly, may continue to germinate gradually for a few days longer than indicated. The warmer the temperature within the limit for complete germination, the more rapidly germination took place. A decrease of a few degrees from any given temperature usually retarded germination more than an increase of the

same number of degrees hastened it. This dependence of the rapidity of germination upon temperature was much more marked with some kinds of seeds that with others. Figs. 5–8 show the average rates of germination at different temperatures of a number of different lots each of balsam, cypress, snapdragon, and larkspur

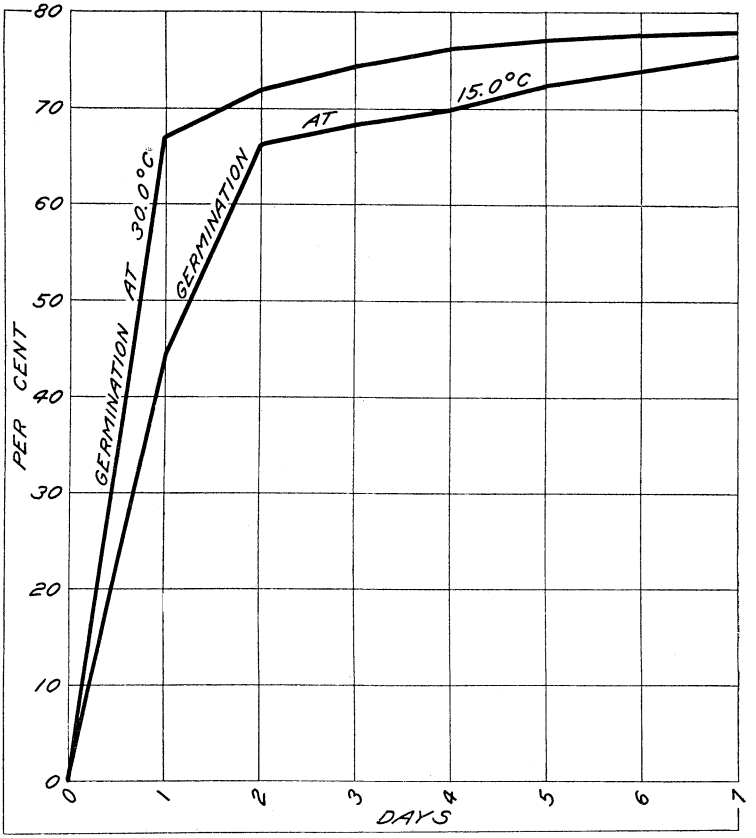

FIG. 6.—Average rate of germination of two lots of cypress seeds

seeds, and illustrate differences in sensitiveness to temperature conditions. Fig. 5, for balsam, is typical also for mignonette, petunia, and portulaca, in so far as the range of temperatures for complete germination is the same. Cypress seeds (fig. 6) germinated more rapidly than any other kind, and almost as rapidly at 15° as at 30° C. Fig. 7, for snapdragon, is typical also for

nasturtium, pansy, and poppy seed. It shows an acceleration of germination by temperatures which were above the maximum for complete germination. In contrast with fig. 7, fig. 8 (for larkspur) shows a retardation of germination as well as a great reduction in total germination by a temperature only 5° C. above the optimum for complete germination.

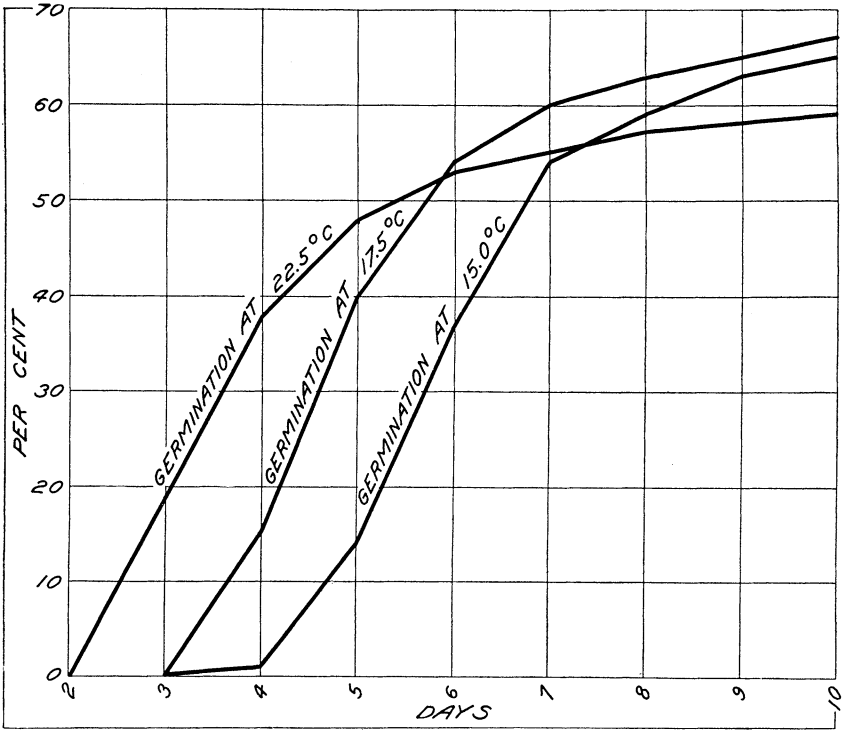

FIG. 7.—Average rate of germination of three lots of snapdragon seeds

The harmful effect of a high temperature on the germination of nasturtium, pansy, poppy, and snapdragon seeds is shown by the fact that all of these seeds germinated more slowly even during the first few days with the temperature alternation 20°–30° C. (not shown in fig. 7, but about equivalent in average temperature to 22.5° C. constant) than at temperatures lower than 22.5° C. Pansy and poppy seeds germinated even less rapidly at 20°–30°

than at 17.5° C. Exposure to 30° for only a few hours each day, therefore, had a retarding effect on germination even during the early days of the test.

A few cases of apparent influence of temperature upon germination require special mention. California poppy seeds germinated much more rapidly and somewhat more completely when the chamber was heated to 30° and allowed to cool very slowly to room temperature than with any of the other conditions of either

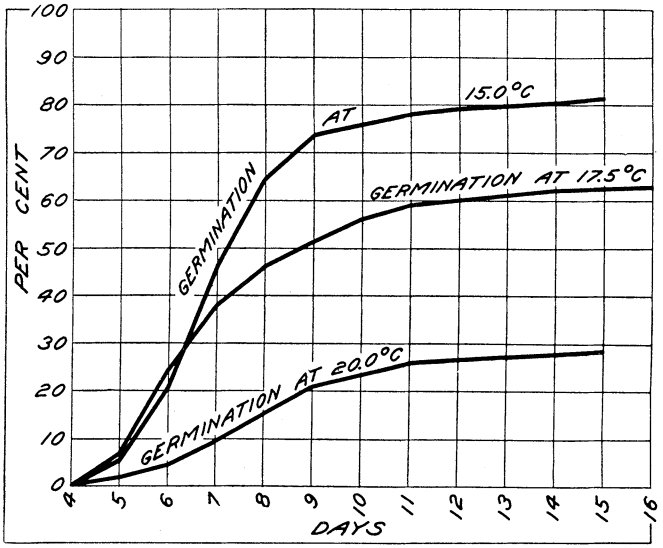

FIG. 8.—Average rate of germination of three lots of larkspur seeds

constant or alternating temperatures used in the series of tests made in 1912.

The cypress seeds were infected with a "damping-off" organism, which destroyed some of the germinated seeds almost as soon as germination began in the tests which were conducted at high temperatures. Some of the nasturtium seeds were badly infected with organisms of decay and with parasitic nematodes, which affected germination more seriously at the higher than at lower temperatures. To avoid difficulties of this kind, so far as possible all sorts of seeds should be tested at temperatures as low as are

consistent with the nature of the seeds in any given case. It is possible also that effective sterilization of the seeds before placing them in the germinator in some cases would alter the conclusions as to optimum temperatures for germination.

The two lots of petunia seeds tested in 1912 germinated somewhat less completely with either of the constant temperatures 20° or 28° than with certain of the alternations of temperatures, especially 20°–30° C. The petunia seeds used in the tests which were made in 1914, however, germinated as completely with any constant temperature from 17.5° to 30° as with the temperature alternation 20°–30° C. In these tests the highest percentage of germination obtained occurred with the constant temperatures 25° and 30°. In testing petunia seeds for germination, probably the most uniformly good results would be obtained with a constant temperature not warmer than 25° or cooler than 22.5°, or with the temperature alternation 20°–30° C.

From 4 to 10 per cent of the sweet pea seeds remained hard at the expiration of the germination tests at different temperatures. No effect of temperature upon the softening and germination of these seeds was noticed.

RAPIDITY OF GERMINATION IN ICEBOX.—In the icebox the first larkspur seeds germinated during the tenth day, the first poppy seeds during the sixth day, and the first snapdragon seeds during the twelfth day. With each kind of seeds, the progress of germination in the icebox was slow. Four weeks were required for a germination test of one lot of larkspur, and three weeks for a germination test of the other two lots of larkspur and some of the lots of poppy. The snapdragon seeds were kept in the icebox over five weeks. At the end of this time germination had practically ceased, but the total percentage of germination (38 per cent) was still but little more than one-half as great as 17.5° C. (67 per cent). The majority of the snapdragon seeds which germinated in the icebox germinated between the twentieth and thirtieth days of the test.

The germination of larkspur no. 250585 began on the eleventh day and was complete in twenty days. At the same time no seeds of larkspur no. 250500 germinated until the nineteenth day,

and germination of this lot continued through the thirty-first day. The rates of germination of these two lots of seeds in the icebox

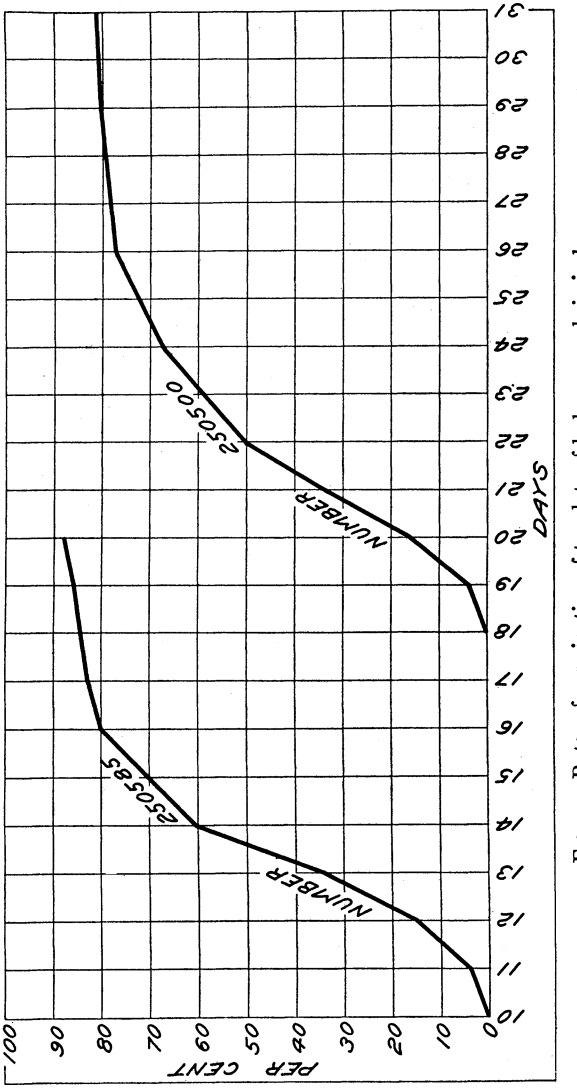

FIG. 9.—Rates of germination of two lots of larkspur seeds in icebox

are shown graphically in fig. 9. Similar but less striking differences occurred in the rates of germination in the icebox of different lots of poppy seeds of each of the three species tested.

RAPIDITY OF GERMINATION BETWEEN AND ON TOP OF BLOTTERS.—In 1914 the poppy seeds were tested simultaneously on top of blotters and between blotters. Except in the icebox, the position of the seeds did not affect the rapidity of germination. In the icebox *Papaver somniferum*, two lots of *P. rhoeas*, and one lot of the undetermined species germinated much more rapidly between blotters than on top of blotters, while there was no difference with the other two lots. The greatest difference was with

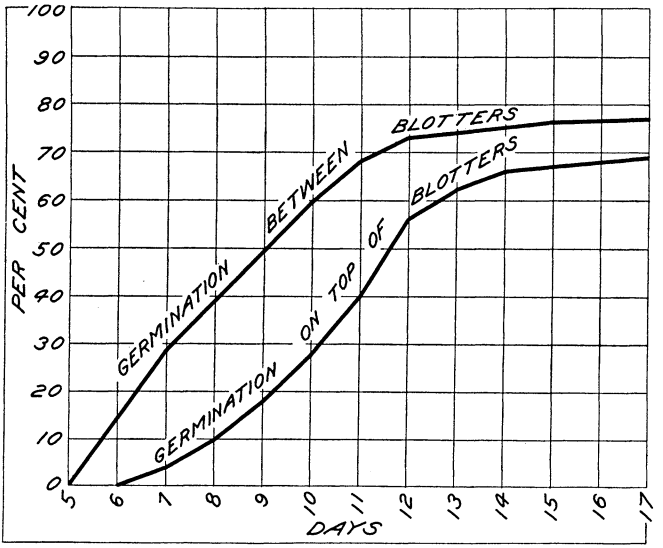

FIG. 10.—Average rates of germination in icebox of six lots of poppy seeds, between blotters and on top of blotters.

one lot of *P. somniferum*, only 5 per cent of which germinated in the first seven days when on top of blotters, in contrast with 51 per cent between blotters. As the temperature of the icebox was very cool, the further reduction of temperature on the surface of the blotters by evaporation probably was sufficient to retard the germination of these lots, and also may explain the lower total germination on top of the blotters. Fig. 10 shows the average rates of germination in the icebox of the six lots of poppy seeds which germinated more rapidly between blotters.

Discussion

It is evident from the foregoing facts that the use of warm temperatures usually increases the rapidity of germination of the species investigated, but that comparatively low temperatures are more favorable for completeness of germination. In conducting germination tests of each species, a temperature should be used which is warm enough to accelerate the progress of germination as much as can safely be done. At the same time, it should not be warm enough to prevent the germination of any viable seeds, or to encourage more than is necessary the development of microorganisms.

When the germination temperature is too warm, frequently the germinated seeds make but little growth, and it is impossible to judge the comparative vigor of different lots of seeds. Sometimes weak seeds of little value will germinate when a warm temperature is used, and will then appear to as good advantage as other strong vigorous seeds. If the germination tests are made with a more favorable temperature, both the strong and the weak seeds will germinate, but in this case the difference will be obvious at once. In this case some seedlings make rapid vigorous growth and are normal in appearance, while others have a watery translucent appearance, grow very slowly, and sometimes have begun to decay before emerging from the seed coat. On the other hand, too cool a temperature decreases the germination, increases the time required, increases also the difference in time required by different lots of seeds of the same species, and thus makes uniform procedure with the different lots impossible. This condition is well illustrated by larkspur samples no. 250500 and no. 250585 (fig. 9).

In conducting germination tests of some of the kinds of seeds, considerable latitude is permissible in deciding upon the temperature to be used. With certain other kinds, as larkspur, the temperature requirements for completeness and rapidity of germination fall within narrow limits.

The substratum should be such as to furnish abundant water to the germinating seeds without limiting the supply of oxygen. For this purpose folded blotting paper well moistened with water

is favorable. Most seeds of medium size can safely be tested between folds of blotting paper. Very small seeds do not hold the separate folds of the blotting paper apart so as to allow circulation of air between them. To insure a sufficient supply of oxygen, such seeds should be tested on top of the moist blotting paper. Candytuft seeds were tested on top of the blotting paper, not because of their size, but because of their mucilaginous covering, which softens when the seeds are wet and sticks the seeds insecurely to both the upper and lower layers of the blotting paper, thus increasing the danger of loss or displacement of the seeds when the blotters are opened to count the germinated seeds. Pansy seeds have a mucilaginous covering similar to the covering of candytuft seeds and may well be tested on top of blotting paper, instead of between blotters as in this investigation. Large seeds, such as sweet pea and nasturtium, should be tested between folds of moist canton flannel or other similar material, instead of in moist blotting paper, because the cloth folds around each seed and supplies moisture to a larger portion of its surface than the blotting paper does.

The seeds should be carefully distributed upon the substratum so that no two seeds touch each other. This guards against the spread of microorganisms, and is of special importance with seeds which are infected with such organisms as those which cause the "damping-off" of seedlings.

Table IV shows the conditions which are recommended for use in making germination tests of the kinds of flower seeds included in the investigation, and the number of days necessary for a preliminary estimate of the germinating capacity and for complete germination. The time allowed for preliminary estimate of each kind is the number of days required for the germination of approximately three-quarters (actual proportions in this investigation varied from 0.7 to 0.9) of the seeds of that kind which are capable of germinating under the conditions indicated. The temperatures given are those which it is thought will give best results with each kind of seeds when both completeness and rapidity of germination are considered. With many lots of seeds germination will be com-

plete in fewer days than are indicated for the completion of the test, and perhaps in exceptional cases a few days longer will be necessary.

Petunia seeds are the only kind for which an alternation of temperatures is recommended, although sweet peas also will germinate as well at 20°–30° C. as with a constant temperature.

TABLE IV

CONDITIONS RECOMMENDED FOR USE IN MAKING GERMINATION TESTS

SEEDS	SUB-STRATUM	TEMPERATURE	NO. OF DAYS FOR	
			Preliminary estimate	Complete test
Balsam	BB*	20° C.	3	5
California poppy	BB	20°	3	8
Candytuft	TB	20°	3	8
Cosmos	BB	20°	3	6
Cypress	TB	20°	2	5
Larkspur	BB	15°	8	15
Marigold	BB	20°	3	6
Mignonette	BB	20°	4	8
Nasturtium	C	17.5°	7	10
Pansy	TB	17.5°	6	12
Petunia	TB	20°–30° or 22.5° C †	5	10
Pink	TB	20°	2	6
Papaver somniferum	TB	15°	4	8
Other poppies	TB	15°	5	10
Portulaca	TB	20°	3	6
Snapdragon	TB	17.5°	6	10
Sweet pea	C	22.5° or 20°–30° †	5	10
Zinnia	BB	20°	3	6

* Letters used in this column indicate: BB, between blotters; TB, top of blotters; C, cloth (canton flannel).

† Either temperature condition may be used, but 20°–30°C. is probably preferable for petunia.

Petunia seeds will germinate almost as well, and frequently quite as well with the constant temperature 22.5° or 25° C. as with the alternation 20°–30° C., and either of these constant temperatures may be used for approximate results when it is inconvenient to maintain the two temperatures 20° and 30° C. Nasturtium, pansy, and snapdragon seeds will germinate about as completely (although more slowly) with the constant temperature 15° as 17.5° C. These kinds may be tested also at 20° C., although a

lower temperature is somewhat more favorable. Such considerations make it possible to test all the kinds of seeds investigated with approximately optimum conditions by maintaining only three different temperatures. These three temperatures may be either 15°, 20°, and 22.5°, or 15°, 20°, and 30° C., according as petunia and sweet pea seeds are to be tested with a constant temperature (22.5°) or with an alternation of temperatures (20°–30° C.). It should be emphasized, however, that probably more uniformly good results would be obtained by using for each species the temperature indicated in table IV.

GREENWICH, CONN.